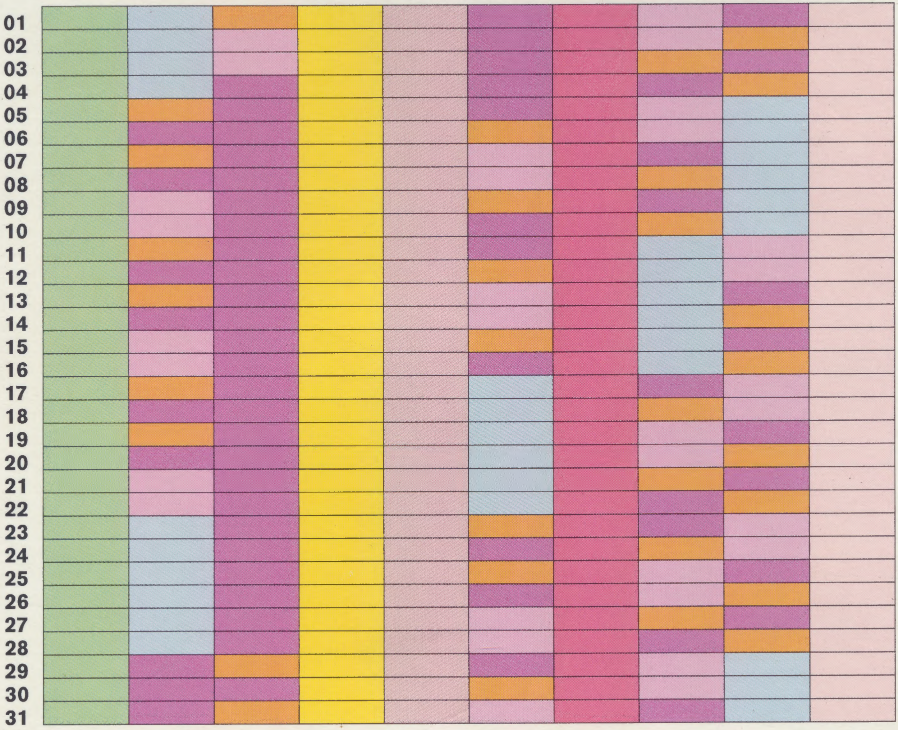
Brian Eno | **JANUARY 07003**



Bell Studies for The Clock of The Long Now

01	Fixed ratio harmonic bells	**23:22**
02	Changes where bell number = repeat number	**03:30**
03	2 harmonic studies	**06:05**
04	Deep glass bells (with harmonic clouds)	**03:17**
05	Dark cracked bells with bass	**01:59**
06	German-style ringing	**03:19**
07	Emphasizing enharmonic partials	**03:01**
08	Changes for January 07003, soft bells, Hillis algorithm	**10:40**
09	Lithuanian bell study	**01:26**
10	Large bell change improvisation	**01:23**
11	Reverse harmonics bells	**02:45**
12	Bell improvisation 2	**01:40**
13	Virtual dream bells, thick glass	**03:59**
14	Tsar Kolokol III (and friends)	**03:59**
15	1st -14th January 07003, hard bells, Hillis algorithm	**05:09**

Composed, performed and produced by Brian Eno

www.longnow.org **www.enoshop.co.uk**

Brian Eno | **JANUARY 07003** | Bell Studies for The Clock of The Long Now

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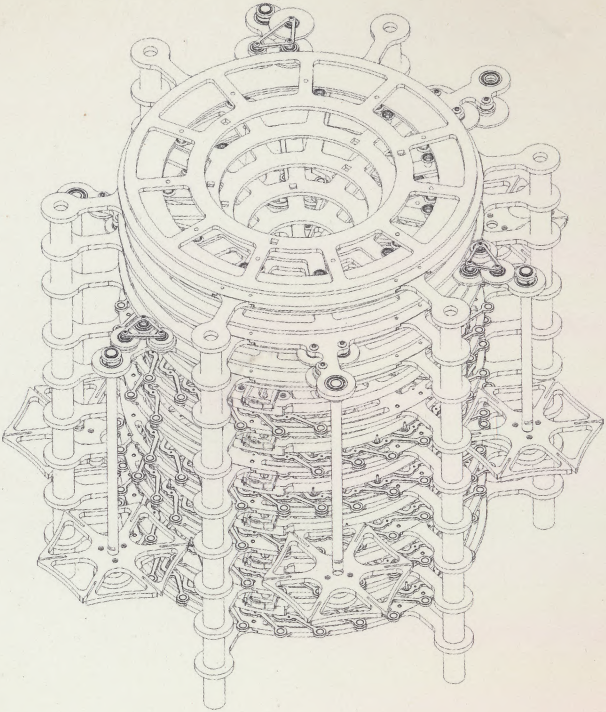


10,000 Year Clock prototype. Courtesy of The Long Now Foundation.

Bells and their history

and

The Long Now Foundation

ABOUT BELLS

The casting of bells is an ancient art that requires the convergence of several technological skills including the making of moulds, and an understanding of the heating and fusing of metals and alloys. The Egyptians made 'closed bells' – also known as crotals - using plaster moulds from about 2000 BC. Over the next 1000 years, small open bells were cast in northern Iran, and by 850 BC, Assyrian bronze founders were experimenting with the acoustic properties of different ratios of tin and copper in their bells.

By the 5th century BC, meanwhile, the Chinese had settled on an alloy of four parts copper to one part tin for bell-making. This ratio is still in common use in modern bell foundries.

The first recorded Christian bellfounders were the smiths Tasag, Cuana and Mackecht, whom St Patrick took to Ireland in the 5th century, although the bells they made were forged rather than cast - probably more like cowbells. The development of cast church-bells was fostered by the Italian Benedictines beginning in about 530AD. As their order spread, they established bellfoundries in monasteries all over Western Europe, and became the main suppliers of bells.

From about the 11th century, treatises on metallurgy and bell-founding encouraged improvements in technique and design, and the craft passed from clerical into lay hands, although the secrets involved were very carefully guarded.

The advent of artillery cannon in the 14th century provided an unexpected boost to bell manufacture: the cannon used almost exactly the same alloy as bells and were made by similar methods. In order to have the security of a local arsenal, cities offered foundry sites and special privileges to bell-founders who would settle within their walls. The same supply of metal would be made into cannon in wartime and back to bells after hostilities.

In Europe in the 17th Century the perfection of clocks increased the usefulness of clock-tower chimes and led to an interest in their musical possibilities. This favoured founders who could cast and tune bells in musical scales, and the most prominent early makers of well-tuned bells were the migrant Hemony brothers from Lorraine. Their work was mostly commissioned in Germany, Holland and Flanders, where they cast many bells including over fifty carillons with ranges of 26 to 37 bells.

During the 17th and 18th centuries bell-founding was influenced by the wealthy Russian monasteries, who increased the number of small bells in their bell sets and added larger ones. Since these bells were stationary rather than swung they exerted no lateral thrust on the buildings that housed them.

The biggest bells are physically much larger than any other instruments - the great Tsar Kolokol bell which sits broken in the Kremlin weighs 200,000 kilograms and is nearly seven metres in diameter; the 'Emelle' bell, cast in Korea in the 7th century, is 72,000 kilograms. Objects such as these remained the largest castings made until modern ship propellers. What has to be borne in mind is that these bells - like all bells - were made in one casting, which means that 200,000 kilograms of metal had to be brought to temperature and poured in one continuous operation. As a technological feat (and allowing for inflation) this is perhaps comparable to the level of coordination required to launch an Apollo into space.

The 20th century saw many technical improvements in bell-founding, including better mould-making materials, better temperature control, and, importantly, better ways of tuning and measuring the pitch of the overtones of the bells. Recent innovations in Holland have involved the use of computers to design bells, modifying the proposed shape until it produces the required overtone series.

All instruments produce their own characteristic partial or overtone series, but what distinguishes bells is that their overtones are not necessarily in concordant relationships - that's to say, they are not necessarily simple multiples of the lowest frequency. A clarinet, for example, produces strong overtones at even multiples of the frequency of the fundamental tone, whereas bells rarely produce such pure overtones, with many bells having overtones with no simple numerical relationship to each other.

In England the lowest note of a church bell - which lasts longest - is called the 'hum note'. The next overtone - which is approximately, but rarely exactly, an octave above it, is the most strongly heard note, and is thus called the 'fundamental'. The next two overtones are called the 'tierce' and the 'quint', and they are approximately a third and a fifth above the fundamental. The tierce is usually a minor third (although recent Dutch experiments with computer aided design have shown bell-makers how to reliably produce 'major' bells). About one octave above the fundamental is the 'nominal' - a short-lived overtone which helps to define the perceived pitch of the bell.

When the fundamental and the nominal are not a true octave apart, a partial called the 'strike note' may be audible at the instant of striking. This overtone is a difference tone, the result of the interaction of other tones. It is still hotly debated whether its presence adds or subtracts from the overall beauty of the bell.

Above the nominal there are further partials in more or less dissonant relationships to each other and the lower overtones, but their decay is very rapid so they do not affect the perceived pitch of the bell. They do, however, affect the perception of brightness and richness that the bell gives at its attack, and the individual character of a bell is very much to do with the perception of its higher partials. The larger the bell, the lower in frequency the whole overtone series is, and the more perceptible it becomes.

The experiments on this CD sometimes try to simulate existing bells, and (perhaps more profitably) imagine different sorts of bells, bells which may indeed be physically unmakeable. Some of these hypothetical bells have idealized overtone series - where each overtone is the same pure multiple of the one below it. Other hypobells explore reversals or suspensions of some physical laws: what would happen if the highest partials lasted longest? What if the lowest notes were the first to speak, whilst the higher partials appeared later? What would a large bell made entirely of glass sound like? What if the first chaotic milliseconds of a bell's ring could be extended over minutes? What if a bell became a drone?

When we started thinking about The Clock of The Long Now, we naturally wondered what kind of sound it could make to announce the passage of time. Bells have stood the test of time in their relationship to clocks, and the technology of making them is highly evolved and still evolving. I began reading about bells, discovering the physics of their sounds, and became interested in thinking about what other sorts of bells might exist. My speculations quickly took me out of the bounds of current physical and material possibilities, but I considered some licence allowable since the project was conceived in a time scale of thousands of years, and I might therefore imagine bells with quite different physical properties from those we now know. And as I started trying to make bell sounds with my synthesizers, I got diverted by some of the more attractive failures...

ABOUT "JANUARY 07003"

Campanology - change-ringing - is one of England's more eccentric contributions to the musical landscape. By the 1600's, many churches had numbers of tuned bells in their belfries, and these seem to have been rung in simple sequence, over and over. About that time a new development arose. Ringers became interested in trying to ring all the possible permutations of their bells, and it is this pursuit that has become known as change-ringing. Stated briefly, change-ringing is the art (or, to many practitioners, the science) of ringing a given number of bells such that all possible sequences are used without any being repeated. The mathematics of this idea are fairly simple: n bells will yield n! sequences or changes. The ! is not an expression of surprise but the sign for a factorial: a direction to multiply the number by all those lower than it. So 3 bells will yield 3x2x1 = 6 changes, while 4 bells will yield 4x3x2x1 = 24 changes. The ! process does become rather surprising as you continue it for higher values of n: 5! = 120, and 6! = 720 - and you watch the number of changes increasing dramatically with the number of bells.

What interests change-ringers is finding ways to arrange all the permutations of a given set of bells into a logical, playable and memorable sequence (since no change may be repeated, no scores may be used, no bell may occupy the same position for more than two consecutive changes, and a whole method must be rung from memory). This becomes an issue with larger numbers of bells, and with a peal of 8 bells and therefore 40240 changes - not uncommon in English churches - it can be a very complex exercise with many different solutions.

The following chart (fig 1) shows the first part of an early solution for six bells, as recorded by Richard Duckworth in his 1671 book "Tintinnalogia". We now call this method Plain Bob Minor: the alternation of three pairs of bells reversing position and then the two inner pairs reversing. If you continue this process you will end up back where you started - but without having used all the possible permutations of the bells. So the art of traditional bell composition lies in finding systematic dodges that will nudge the sequence into new territory without repetition.

Naturally, being English, these solutions have arcane names and have been the subject of many heated belfry discussions - often the only form of heating to be found in many English churches. Here is one of the oldest,

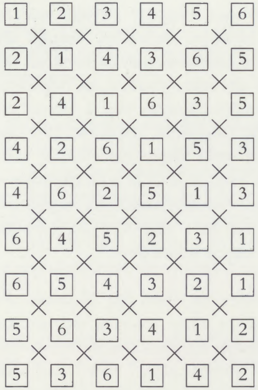


fig 1

called Plain Triples, as described by the great bell composer Fabian Stedman in his 1677 book "Campanologia":

> "All the bells have a direct hunting course. All peals upon six bells wherein half the changes are triples, will go upon seven according to this method here prickt; two of the changes upon six being always made at the leadings of the Treble, the six hind most bells making them: the first is a triple change brought in by the course of the bells, and the next must either be double or single according to the method of changes upon six"

Some of the other methods, with descriptions every bit as lucid and names every bit as charming, are Plain Bob Minimus, Grandsire Doubles, Restoration Triples, Tendring's Six Score, Stedman's Principle, Whirligigge, My Honey, The Wild Goose Chase, Cambridge Surprise Minor, Oxford Treble Bob, Christmas Eve, Paradox on Five Bells, Plain Hunt on Six, and Imperial Bob.

As the only English member of the Long Now Foundation Board, I felt I could slightly internationalize - or eccentricalize - the clock project by introducing something of my hereditary campanological interests. Looking at the surprising world of !, I noticed that a 10 bell peal would yield 10! = 3,628,800 changes. I also noticed that this is very close to the number of days in 10,000 years - the proposed minimum lifespan of the Clock.

This attractive near-coincidence made me imagine a method which would produce such a series of changes but which would also be generated in such a way as to act as a calendar. What that means is that a listener, hearing the bells on a day in the future, should be able, if the algorithm that generates the series is known, to calculate exactly the number of days since the series started playing. Seen from the other end, it would enable

me as a composer to know what change would be playing on a given day in the future. That was the part that interested me: I wanted to hear the bells of the month of January, 07003 - approximately halfway through the life of the Clock.

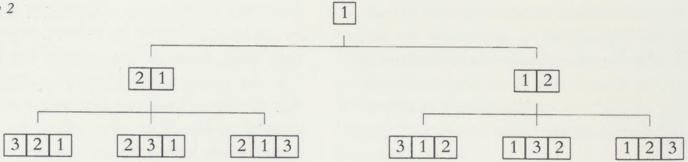
I had no idea how to generate this series, but I had a good idea who would.

I wrote to Danny Hillis asking whether he could come up with an algorithm for the job. Yes, he wrote back, and in fact he could come up with an algorithm for generating all the possible algorithms for that job. Not having the storage space for a lot of extra algorithms in my studio, I decided to settle for just the one.

Danny's explanation of his algorithm and a mechanism by which it could work begins as follows:

> Each day the ringer mechanism rings a change, which is a ring sequence consist ing of one permutation of the bells. The mechanism is designed to work through all of the permutations of 10 bells before repeating.
>
> To understand the algorithm used for generating the permutations, try writing down the permutation of a smaller number of bells, say three, on a piece of paper. First write down the name of the first bell, 1, in the center of the paper. Now notice that the second bell can ring either before the first or after it, in other words it can occur in one of two places, with respect to the first bell. Write down both these pos sibilities on the next line, one on either side. Now, notice that when we have two bells in place, there are three places to put the third bell. You can write down each of these on the line below. That generates all six permutations of three bells:
>
> To generate the permutations of four bells you would need to place the fourth bell in each of the four possible position for each of these six three-bell permutations, and so on. The proposed mechanism uses an algo rithm very similar to this to generate the permutations. The mechanism is modular, with one ring module for each of the ten bells. Each module has a wheel that counts the position of the bell in the sequence, relative to the lower numbered bells. For example, the third bell has a wheel with three positions, selecting whether the third bell appears, before, between, or after bells one and two. The fourth bell has a four-position wheel and, so on. These wheels are used to count though all of the possi

fig 2



bilities, advancing to a new combination each day.

The mechanism actually needs not only to generate the index positions of the bells, but must translate those indices into a sequence. For this it uses another counting wheel in each module that keeps track of how many bells have rung so far in the current change.

A campanologist will notice that Danny's algorithm produces a result which breaks some rules of traditional bell ringing - that no bell shall occupy the same 'place' in more than two consecutive changes, and that place shifts are such that they are physically possible for ringers to play (- so a bell isn't expected to be rung at the end of one sequence and then the beginning of the next, for example). I considered that these rules were breakable because the changes were being generated by a machine, and would be played far enough apart in time (one change a day) for their positional similarities to be irrelevant.

Tracks 2, 8 and 15 all use the sequence for the month beginning Saturday January 1 07003. Track 8, which shows the changes for the whole of that month, employs bells made from a very heavy ceramic-metal compound in the year 05102 (shortly after the original bronze set had finally deteriorated beyond repair due to the hyperacidity of the late 4th millennium). The last track, in some parallel universe, plays the first two weeks of that same January on the original bronze set. Track 2 plays the first few days but in such a way that each bell is struck as many times as its number - so bell 10 is always struck ten times. This breaks every known rule of bell-ringing but makes a pretty noise.

Other tracks explore non-campanological approaches, such as the German 'hit every bell as often as and as hard as possible' approach (track 6), and the Russian 'shock and awe' style (track 14). Track 9 got its title

because Inge, who looks after the studio, said, almost with tears in her eyes, that it reminded her of her homeland's bells. The bells on the first track are constructed in such a way that their harmonic series is intensely idealized, with each harmonic being precisely 1.66 times the pitch of the one below it.

Tsar Kolokol III (and friends) is an attempt at a sonic reconstruction of the biggest bell ever made - which was never heard because it cracked during a fire shortly after being cast. In this piece I imagine the big bell with a few similarly large companions.

Brian Eno, March 2003

Technical and historical information adapted from
"The New Grove Dictionary of Musical Instruments" ed. Stanley Sadie London, 1984.
"Change Ringing - The History of an English Art" ed. J. Sanderson 1987.
"Fundamentals of Musical Acoustics" Arthur H. Benade 1976.

THE LONG NOW FOUNDATION

Stewart Brand, in his book "The Clock of the Long Now: Time and Responsibility", presented what can be read as the mission statement of the Long Now Foundation:

> "Civilization is revving itself into a pathologically short attention span. The trend might be coming from the acceleration of technology, the short-horizon perspective of market-driven economics, the next-election perspective of democracies, or the distractions of personal multi-tasking. All are on the increase. Some sort of balancing corrective to the short-sightedness is needed - some mechanism or myth which encourages the long view and the taking of long-term responsibility, where "the long term" is measured at least in centuries".

The Foundation's first major project was the construction of The Clock of The Long Now, a mechanism designed by Danny Hillis. This is his original (1993) proposal for the Clock:

> "When I was a child, people used to talk about what would happen by the year 2000. Now, thirty years later, they still talk about what will happen by the year 2000.

The future has been shrinking by one year per year for my entire life.

I think it is time for us to start a long-term project that gets people thinking past the mental barrier of the Millennium. I would like to propose a large (think Stonehenge) mechanical clock, powered by seasonal temperature changes. It ticks once a year, bongs once a century, and the cuckoo comes out every millennium".

Stewart Brand comments:

"Such a clock, if sufficiently impressive and well-engineered, would embody deep time for people. It would be charismatic to visit, interesting to think about, and famous enough to become iconic in the public discourse. Ideally it would do for time what the photographs of Earth from space have done for thinking about the environment. Such icons reframe the way people think".

CURRENT FOUNDATION PROJECTS

The Long Now Foundation receives all profits from sales of this CD. Back in 1996 (or 01996, as Long Now writes it, to forestall the Y10K problem), the foundation was established in San Francisco, California, to foster long-term thinking and long-term responsibility.

"January 07003, Bell Studies for the Clock of the Long Now" may be purchased from The Long Now Foundation's website at www.longnow.org and Brian Eno's web store at www.enoshop.co.uk.

The best-known project of The Long Now Foundation is a 10,000-year Clock, designed by Danny Hillis, for which the sounds on this CD were created. The eventual monument-scale mechanical-digital Clock may live inside a white limestone mountain in eastern Nevada, serving as a kind of icon of sustainability or "statue of responsibility." Burdened with no explicit agenda or message, but hopefully beautiful and impressive, all it is meant to do is give the visitor permission to think long-term. The first working prototype of the Clock, nine feet high, may be seen at the Science Museum in London.

Several other Long Now projects comprise a growing array of services under the overall goal of a "10,000-year Library." As of 02003 they were:

The Rosetta Project (www.rosettaproject.org) is a website mustering so far 1,400 living human languages, with a goal of collecting all the languages in the world (some 6,000). In addition to the scholarly online service, the languages are being micro-etched permanently on small metal disks, the ultimate "hard copy."

Long Bets (www.longbets.org) is another online service, in this case offering "accountable predictions" over the very long term (thousands of years). Anyone may go on the site and permanently register Predictions or Bets (with money at stake), and discuss and vote on other Predictions on the site.

The All Species Foundation (www.all-species.org) is a non-profit organization dedicated to the complete inventory of all species of life on Earth within the next 25 years - a human generation. One of the great scientific goals of a new century, it also offers an unsurpassable adventure: the exploration of a little-known planet.

Long Server is the name for an effort, still emerging, to help solve the growing problem of preserving digital materials, most of which become unreadable every ten years because of fast-moving digital technology.

A book about Long Now and the ideas behind the Clock, featuring Brian Eno and other founders of the project, is titled THE CLOCK OF THE LONG NOW, by Stewart Brand. It can be purchased from the Long Now website or Amazon.com

Your ideas to improve Long Now's various projects, and suggestions for new ones, are welcome at www.longnow.org

Stewart Brand, President

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With special thanks to the members and staff at the Long Now Foundation, Marlon Weyeneth, Catherine Dempsey, Paolo Salvagione and Jane Geerts. Cover illustration and art direction, Brian Eno. Design and layout Sam Blunden.